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The Effect of Intensity of Tillage and Herbicide Application on Spring Planted Maize (*Zea mays* L.) and its Weeds

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Abstract

An experiment was conducted to study the effect of tillage intensity and herbicide application on spring planted maize (*Zea mays* L.) and its weeds. The experiment comprised three tillage treatments i.e. no tillage, minimum tillage and conventional tillage and three treatments of herbicides viz. weedy check, Pendimethalin @ 990 g a.i. ha^{-1} as a pre-emergence herbicide and Atrazine @ 475 g a.i. ha^{-1} as a post-emergence herbicide along with weedy check. The herbicides and tillage significantly decreased weed density, fresh and dry weight of weed, 1000-grain weight and grain yield. All treatments decreased weed density by 51.15-86.84 % and increase the grain yield by 6 to 71% compared with control. The study concluded that mould board ploughing + Pendimethalin @ 990 g a.i. ha^{-1} was more effective for controlling weeds and obtaining higher grain yield under the Faisalabad condition, Pakistan.

Key words: Spring maize, Tillage, Weeds, Herbicide, Pakistan

Introduction

Maize (*Zea mays* L.) is the third most important cereal crop after wheat and rice in Pakistan and mostly consumed as human food and animal feed and provides raw material for food industry. According to estimation, 75% of the total production of maize is used as food by the farming community and remaining finds its way in starch manufacturing industry, poultry feed and food grain sales (Muhammad, 1979). In the advanced countries, about 90% of maize is used for making animal feed and other industrial products (Rajoo, 1998). In Pakistan total area under maize crop during 2008 was 1.015 million hectares and production was 3.313 million tones with average yield of 3264 kg ha^{-1} (GOP, 2008). Although the soil and climatic conditions of Pakistan are favorable for maize production but its per hectare yield is very low as compared to other maize growing countries of the world.

Among various factors responsible for low yield, weed infestation is of supreme importance. Weeds are problem particularly for those farmers who have large holdings. Because of acute shortage of labor and frequent monsoon rains during the early growth period of maize, hand weeding or mechanical weeding operations are usually delayed or left altogether. In such situation, herbicides offer the most effective and economical method of weed control and increase crop yield. Worldwide maize production is hampered up to 40 % by competition from weeds (Oerke et al., 2004). Weeds reduce crop yield by competing for light, water, nutrients and carbon dioxide, interfere with harvesting and increase the cost involved in crop production. Overall, weeds had the highest loss potential (37%) which is higher than loss potentials of animal pests (18%), fungal and bacterial pathogens (16%) and viruses (2%) (Oerke, 2005).

Losses caused by these weeds can be considerably reduced by use of selective herbicides (Shad et al., 1996). Weed control practices in maize resulted in 77 to 96.7 percent higher yield than weedy check (Khan et al., 1998). Weeds can be controlled by cultural, biological and chemical measures. No doubt, cultural methods are still useful tool but it is laborious, time consuming and expensive especially when labour problem is becoming severe day by day (Chikoye et al., 2004). Considering these limitations, chemical weed control is an important alternative. Herbicide application is an efficient way to check weed infestation that helps achieve a speedy breakthrough for increasing maize production.

Tillage is also an effective method of physically controlling weeds; it has been positive effect on herbicides movement and persistency. Herbicide movement may be influenced by placement and tillage. For example, the levels of atrazine, alachlor, and metribuzin in the 1-100 cm depth of soil to be lowest in ridge tillage and greatest in moldboard plough tillage at the end of the growing season (Weed et al., 1995). The maize yield and weed control were similar in plots where integrated inter

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row cultivation and reduced levels of herbicide were compared with the plots to which full rates of herbicide were applied (Buhler et al., 1995). In view of the importance of the problem, following experiment was designed to investigate the efficacy of different herbicides in controlling weeds and consequent effects on various agronomic parameters including yield and yield components of maize crop.

Materials and Methods

Experimental site and treatments

The study was conducted at the Agronomic Research Farm, University of Agriculture, Faisalabad during 2008 to investigate the response of spring planted maize and its weeds to intensity of tillage i.e. no tillage, minimum tillage using chisel plough and conventional tillage using mould board plough and herbicide application i.e. Pendimethalin @ 990 g a.i. ha^{-1} as a pre-emergence herbicide and Atrazine @ 475 g a.i. ha^{-1} as a post-emergence herbicide along with weedy check. Soil under study belonged to sandy loam soil texture having N 0.096%, available P 7.1 ppm, K 185 ppm and pH 8.2. The experiment was laid out in randomize complete block design (RCBD) with split plot arrangements having three replications with net plot size is 6m × 3m.

Crop husbandry

The maize cultivar "Double Top Cross" was sown on 9th of February 2008 in 75 cm apart rows using hand drill and plant to plant distance of 20 cm. Nitrogen and phosphorous were applied @ 150 and 100 kg ha^{-1} in the form of Urea and Diammonium phosphate, respectively. Whole of the phosphorous and half of the nitrogen was side drilled at the time of sowing while remaining half of the nitrogen was top dressed at the time of 2nd irrigation. Pre-emergence herbicide was applied just after sowing while post-emergence herbicide was applied after 2nd irrigation at field capacity by "Knapsack" hand sprayer using flat fan nozzle. Volume of spray was determined by calibration with water and was used at 300 l ha^{-1}. All other agronomic practices were kept normal and uniform for all the treatments combinations.

Measurements

Data on weed density m^{-2} after 20 DAS, 40 DAS and harvested were counted from a unit area of one square meter at three places selected randomly in each plot and then average was taken. Weed biomass (g m^{-2}) was recorded from an area of $1m^2$ by cutting the weeds at ground level from randomly selected area of I square meter at two different places before the harvest of crop and then oven dried at 70 ^oC for 72 hours till the constant weight. Plant height (cm), number of grain rows per cob, number of grains per cob, 1000-grain weight (g) and grain yield (t ha^{-1}) were recorded from five randomly selected plants from each plot. The data was subjected to the analysis using Fisher's analysis technique and the means were separated by the least significant difference test (LSD) at 0.05 level of probability to compare the significant treatment's means (Steel et al., 1997).

Results and Discussion

Weeds

Cyperus rotundus (Deela) and *Dactyloctenium aegyptium* (Madhana grass) were the dominant weeds present in the field and *Trianthema partulacastrum* (Itsit), *Cynodon dactylon* (khabal Grass), *Solanam nigram* (Peelac), *Phyllanthus niruri* (Hazardani) and *Achyranthus aspara* (Puth kanda) were also noticed in the experimental area. Among all these weeds *C. rotundus* was the dominating weed.

Total Weeds Density at 20 DAS (m^{-2})

The total weed density was significantly affected by different tillage practices (Table: 1). The maximum weed density (199.0 m^{-2}) was recorded in chisel ploughing (T_2) against the minimum (100.6 m^{-2}) in no tillage (T_1). The mean increase in total weed density was 89.86% and 45.62% in case of chisel ploughing and mould board ploughing, respectively, over no tillage treatment. The minimum total weed density in no tillage is due to weed seeds present in the soil surface and seeds buried at more depth in both situations, seed can not germinate. While in case of chisel ploughing (T_2) weed seeds got more favorable conditions as compared to other tillage treatments. In case of mould board ploughing (T_3), the weed seeds that were present in upper layer of the soil were spread in deeper layer as result weeds seed density decreased in upper layer and ultimately a decrease in total weed density was observed. These results are in line with the results of Knezevic et al., 2003. Herbicides also significantly affected the total weed density. The maximum (196.0 m^{-2}) was recorded in post emergence application of Atrazine (W_3) and statistically similar (195.8 m^{-2}) with no herbicides application (W_1). The statically minimum (46.56 m^{-2}) total weeds density in W_2 where pre-emergence application of Pendimethalin was done. These results are in close agreement with results obtained by Pandey et al., 2000 and Chikoye et al., 2001, who reported a significant difference in weed density of various weed control treatments. The interaction between tillage intensity and herbicides application was also significant. The maximum total weed density (261.3 m^{-2}) was recorded in no herbicides treatment with chisel

ploughing ($T_2 \times W_1$) and statistically at par (256.0 m^{-2}) with chisel ploughing and post-emergence atrazine @ 475 g a.i. ha^{-1} application treatment ($T_2 \times W_3$). The minimum weed density was recorded in no tillage and Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} treatment ($T_1 \times W_2$) but was statically at par with mould board plough and Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} ($T_3 \times W_2$). The lower weed density due to herbicide application over weedy check might have been due to the mortality of weeds or suppress in these treatments while the maximum weed density was found in weedy check due to unchecked weed growth as no weed control practices were applied and the soil were ploughed. These results are supported by those of Sharma and Thakur (1998), Porwal (2000), Toloraya et al. (2001), and Adigun and Lagoke (2003) who reported maximum weed density in weedy check treatments.

Weeds Density at 40 DAS (m^{-2})

The total weed density was significantly affected by different weed control practices after 40 DAS (Table: 1). Chisel ploughing (T_2) resulted in significantly maximum weed density (224.6 m^{-2}), followed by mould board ploughing (172.3 m^{-2}) where as no tillage (T_1) showed (124.9 m^{-2}) the minimum weed density. The mean increase in total weed density was 89.86% and 45.62% in case of chisel ploughing and mould board ploughing, respectively, over no tillage treatment. The maximum weed density was recorded in chisel ploughing due to provision of favorable condition for weed seed germination and increased the area of seed bank weed. Herbicides also significantly affected the total weed density. As for as herbicides application concerned, the statically minimum (122.1 m^{-2}) total weed density in W_2 treatment where pre-emergence application of Pendimethalin was applied. The maximum (233.2 m^{-2}) weed density was recorded in no herbicides application treatment (W_1) and followed by post-emergence application of Atrazine (W_3) These results are in close agreement with results obtained by Pandey et al., 2000 and Chikoye et al., 2001, who reported a significant difference in weed density of various weed control treatments. The interaction between tillage intensity and herbicides application was also significant. The maximum total weed density (307.3 m^{-2}) was recorded in no herbicides treatment with chisel ploughing ($T_2 \times W_1$). The minimum weed density (94.0 m^{-2}) was recorded in no tillage and Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} treatment ($T_1 \times W_2$). The ranking order of weed density in treatments without herbicides application was no tillage < nould board ploughing < chisel ploughing and the weed data indicated that perennial weeds were more abdundant in no tillage than mould ploughing and chisel ploughing. These results are in agreement with Demjanova et al., (2007) and Marwal et al., (2007) who stated weed control practices was significantly reduce the weed density.

Weeds Density at Harvest (m^{-2})

The tillage intensity and herbicides application have significant individual as well as combined (interaction) on the total weed density at harvest. The no tillage (T_1) significantly reduces the total weed density (83.0 m^{-2}) while the maximum (171.9 m^{-2}) was observed in chisel ploughing (T_2). Total weed density with mould board ploughing (141.3 m^{-2}) was in between these two treatments. As far as herbicides application concerned, minimum total weed density (93.67 m^{-2}) was recorded in Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} (W_2) and the maximum was (180.1 m^{-2}) in control (W_1) where no herbicide was applied. These results are in agreement with sing et al., (1998). The interaction of the tillage intensity and the herbicides application was significant. The statically minimum total weed density (64.3 m^{-2}) was observed in treatment combination T_1W_2 (no tillage + Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1}) and it was followed (71.7 m^{-2}) by T_1W_3 (no tillage + Atrazine (post-Em.) @ 475 g a.i. ha^{-1}). Maximum total weed density (229.7 m^{-2}) was observed in treatment combination T_2W_1 (chisel ploughing + no herbicide). The lower weed density due to herbicide application over weedy check might have been due to the mortality of weeds or suppress in these treatments while the maximum weed density was found in weedy check due to unchecked weed growth as no weed control practices were applied and the soil were ploughed. Data trend showed that application of both the weedicides with no till conditions reduced the weed density. These results are in agreement with Khan and Haq, (2004).

Weed Dry Weight at Harvest (g m^{-2})

The effect of different weed control practices on weed dry weight at harvest was significant (Table 2). All weed control practices produced significantly lower dry weight of weeds and the minimum dry weight (273.3 g m^{-2}) was recorded in no tillage (T_1). The effect of herbicides application was also significant. As regards herbicide treatments, the maximum and minimum were recorded in no herbicide treatments (W_1) and atrazine (post-Em.) @ 475 g a.i. ha^{-1} (W_3). The interaction between tillage intensity and herbicides application was also significant. The maximum dry weight (475.7 g m^{-2}) was recorded in chisel

Table 1 Effect of Different Tillage Intensity and Herbicides application on weed density (m^{-2})

Treatments	Weed Density 20 DAS	Weed Density 40 DAS	Weed Density at harvest
T1=No Tillage	100.6 c	124.9c	83.0 e
T2=Chisel Plough	191.0 a	224.6a	171.9a
T3=M.B. Plough	146.8 b	172.3b	141.3 b
LSD=0.05	5.088	5.923	4.093
W_1= No Herbicides	195.8 a	233.2 a	180.1 a
W_2= Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1}	46.56 b	122.1 c	93.67 c
W_3= Atrazine (Post-Em.) @ 475 g a.i. ha^{-1}	196.0 a	166.4 b	122.6 b
LSD=0.05	5.399	4.017	1.942
T1 × W1	130.0 c	157.7 e	113.3 f
T1 × W2	39.0 e	94.0 g	64.3 i
T1 × W3	132.7 c	123.0 f	71.7 h
T2 × W1	261.3 a	307.3 a	229.7 a
T2 × W2	55.7 d	154.7 e	123.3 e
T2 × W3	256.0 a	211.7 c	162.7 c
T3 × W1	196.0 b	234.7 b	197.3 b
T3 × W2	45.0 e	117.7 f	93.3 g
T3 × W3	199.3 b	164.7 d	133.3 d
LSD=0.05	8.344	6.958	3.363

ploughing and no herbicides application treatments ($T_2 \times W_1$) whereas the minimum (138.3 g m^{-2}) was recorded in no tillage and atrazine (post-Em.) @ 475 g a.i. ha^{-1} ($T_1 \times W_3$). Application of both the weedicides with no till conditions reduced the weed dry weight more significantly as compared to any other treatments. The maximum weed dry was due to no control measures was done in case of tillage intensity (T_1) and pre-emergence herbicides treatments (W_1) which is unable to control the weed at the lateral stages of crop. The difference in the effectiveness between pre-emergence and post emergence application pf herbicides might be due to difference in their mode of action. Sharma et al., (1998) and Saini et al., (2000) had also reported lower dry matter of weeds in weed control treatments.

B. Maize (*Zea mays* L.)

Plant Height of Maize (cm)

Data regarding to Plant height (Table 2) revealed that the tillage intensity, herbicides application and their interaction was significantly affected. The maximum plant height (196.7 cm) was recorded in case of mould board ploughing whereas the minimum was in no tillage (151.1 cm). Different herbicide doses were significantly affected the plant height. The significantly maximum was in Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} (W_2) and followed by W_3 treatment. As regard the interactive effect of tillage and herbicide application, the maximum value of plant height (206 cm) was observed in treatment combination mould board ploughing + Pendimethalin (T_3W_2) and statistically at par with 203.7, 201.0, 199.3 cm in case of chisel ploughing + Pendimethalin (T_2W_2), mould board ploughing + atrazine (T_3W_3) and chisel ploughing and atrazine (T_2W_3). These results are in agreement with Salazari, 2001.

No. of Grain Rows per Cob

Results regarding number of grains per cob are summarized in Table 3. The data shows that both the tillage systems and herbicide application have significant individual as well as combined (interaction) effect on number of grain rows per cob. The mould board ploughing (T_3) and chisel ploughing (T_2) gave the statistically maximum number of grain rows per cob (16.15 and 15.67 respectively). The statistically maximum number was recorded in Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} which was at par with atrazine (post-Em.) @ 475 g a.i. ha^{-1} treatment. As regard the interactive effect of tillage and herbicide application, the maximum value of number of grain rows per cob (16.88) was observed in treatment combination mould board ploughing + Pendimethalin (T_3W_2) against the minimum (13.67) was in chisel ploughing with Pendimethalin (T_1W2).

Number of Grains per Row

The results pertaining to number of grains per row revealed that the tillage intensity was significant. The maximum (41.67) was in mould board ploughing while minimum was in the no tillage (32.22). Among the herbicides treatments, the maximum (40.67) number of grains per row

Table 2 Effect of Different Tillage Intensity and Herbicides application on Fresh weight, dry weight of weeds and plant height, Number of grain rows per cob of maize at harvest

Treatments	Fresh Weight at Harvest	Dry Weight at Harvest	Plant Height (cm)	Number of grain rows per cob
T1=No Tillage	895.9 c	273.3 c	151.1 b	13.27 b
T2=Chisel Plough	1220.0 a	366.2 a	193.3 a	15.67 a
T3=M.B. Plough	1103.0 b	310.9 b	196.7 a	16.15 a
LSD=0.05	4.576	3.201	4.756	0.8543
W_1= No Herbicides	424.0 a	440.0 a	167.6 c	13.96 b
W_2= Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1}	961.0 b	312.3 b	191.2 a	15.70 a
W_3= Atrazine (Post-Em.) @ 475 g a.i. ha^{-1}	834.3 c	201.1 c	185.3 b	15.44 a
LSD=0.05	7.134	5.233	2.254	0.3788
T1 × W1	1156.0 c	393.0 c	142.7 e	11.67 e
T1 × W2	879.7 g	297.7 e	164.0 c	13.67 d
T1 × W3	651.7 h	138.3 I	155.7 d	14.48 cd
T2 × W1	1649.0 a	475.7 a	177.0 b	14.80 cd
T2 × W2	1066.0 d	378.7 d	203.7 a	16.55 ab
T2 × W3	943.7 e	244.3 g	199.3 a	15.67 abc
T3 × W1	1465.0 b	451.3 b	183.0 b	15.40 bc
T3 × W2	937.0 e	260.7 f	206.0 a	16.88 a
T3 × W3	907.7 f	220.7 h	201.0 a	16.17 ab
LSD=0.05	12.36	9.065	7.347	1.298

Table 3 Effect of Different Tillage Intensity and Herbicides application on Maize Plant Yield Parameters

	Number of of grains cob^{-1}	Total number Grain $rows^{-1}$	1000-grain weight (g)	Grain Yield (t ha^{-1})
T1=No Tillage	32.22 c	442.6 c	240.1 c	5.489 c
T2=Chisel Plough	40.11 b	631.1 b	273.9 b	8.089 b
T3=M.B. Plough	41.67 a	675.0a	277.0 a	8.422 a
LSD=0.05	0.6167	28.15	1.112	0.1014
W_1= No Herbicides	35.33 c	498.0 c	245.7 c	6.878 c
W_2= Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1}	40.67 a	645.5 a	274.1 a	7.678 a
W_3= Atrazine (Post-Em.) @ 475 g a.i. ha^{-1}	39.00 b	605.2 b	271.2 b	7.444 b
LSD=0.05	0.3703	15.01	0.5588	0.09187
T1 × W1	30.67 h	356.7 i	230.0 g	5.233 e
T1 × W2	34.67 g	472.2 h	245.0 f	5.700 d
T1 × W3	34.33 g	498.7 g	245.3 f	5.533 d
T2 × W1	36.67 f	543.0 f	251.7 e	7.600 c
T2 × W2	43.33 b	717.8 b	287.0 b	8.367 b
T2 × W3	40.33 d	632.6 d	283.0 c	8.300 b
T3 × W1	38.67 e	594.3 e	255.3 d	7.800 c
T3 × W2	44.00 a	746.5 a	290.3 a	8.967 a
T3 × W3	42.33 c	684.2 c	285.3 b	8.500 b
LSD=0.05	0.6414	26.00	1.746	0.2048

was in Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} (W_2) against the minimum was recorded in the no herbicides application treatments (35.33). The interaction between the tillage intensity and herbicides application was significant. The interaction of mould board ploughing and atrazine (post-Em.) @ 475 g a.i. ha^{-1} ($T_3 \times W_2$) application gave the statistically maximum number of grains per row while the minimum (30.67) was recorded in no tillage and no herbicides ($T_3 \times W_3$). The low number of grains per row was due to unchecked growth of weeds and more nutrients were untaken by the weeds, ultimately less food available for the crop.

Total Number of Grains per Cob

Both the tillage systems and herbicides application have significant individual as well as combined (interaction) effect on total number of grains per cob. The statistically maximum total

number of grains per cob (675) was recorded in the mould board plough treatments (T_3) whereas the minimum (442.3) was in no tillage (T_1).Among the herbicides application treatments, the significantly maximum (645.5) total number of grains per cob was recorded with Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} (W_2), followed (W_3) by atrazine (post-Em.) @ 475 g a.i. ha^{-1} (605.2) and the minimum (605.2) was in no herbicide application treatments (W_1). As regard the interactive effect of tillage and herbicide application, the maximum value of number of total number of grains per cob (746.5) was observed in treatment combination mould board ploughing + Pendimethalin (T_3W_2) followed by 717.8 in case of chisel ploughing + Pendimethalin ($T_2 \times W_2$) and the minimum total number of grains per cob (356.7) was recorded in no tillage and no herbicides application interaction treatments ($T_1 \times W_1$). The higher total number of grains per cob was due to effective control by all the control treatments over the weedy check. These results are match with Toloraya et al., 2001.

1000-Grain Weight (g)

The effect of different weed control practices was significant showing the maximum grain yield (277 g) was recorded at mould board ploughing which was 15.36% more than control against the minimum (240.1 g) in no tillage treatment (T_1). Application of different herbicides was also significantly affected the 1000-grain weight. Significantly the maximum grain weight was recorded in plots where Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} was applied. Mean increase in 1000-grain weight was 11.55 and 10.37 % in case of Pendimethalin and atrazine application, respectively, compared with no herbicides. The interaction between the tillage intensity and herbicides application was significantly. The maximum value of 1000-gain weigh (290.3) was recorded in mould board ploughing + Pendimethalin ($T_2 \times W_2$) and significantly minimum (230.0 g) 1000-grain weight was recorded in no tillage and no herbicides application ($T \times W_1$). The minimum 1000-gairns in tillage intensity and herbicides application was due to unchecked growth of weed which ultimately utilized the nutrients fro the soil and hence less photosynthats are available for crop. Toloraya et al., 2001 reported more 1000-grains were in the weed free fields,

Grain Yield (t ha^{-1})

The effect of different weed control practices was highly significant in all treatments i.e. tillage intensity, herbicides application and their interaction. The significantly maximum grain yield (8.422 t ha^{-1}) was obtained in the mould board ploughing (T_3), followed (8.089 t ha^{-1}) by chisel ploughing treatment (T_2) whereas the minimum (5.489 t ha^{-1}) was in no tillage (T_1). Grain yield of maize were affected significantly by different herbicides doses. The maximum grain yield (7.678 t ha^{-2}) was recorded in Pendimethalin (Pre-Em.) @ 990 g a.i. ha^{-1} (W_2) against the minimum (6.878 t ha^{-2}) in control where no herbicide was applied (W_1). The interaction of tillage intensity and herbicides application was also highly significant. The maximum grain yield (8.97 t ha^{-1}) of spring planted maize was observed in treatment combination mould board ploughing + Pendimethalin ($T_3 \times W_2$) that was 71.37 % higher against the minimum grain yield in no tillage + no herbicide where no weed control practice was applied (T_1W_1). Adeoye et al., (1982) reported that deep tillage increased the grain yield of maize by about 10 %. Fredrick and Bauer (1996) noted that deep tillage has been found to increase grain yield by increasing number of cobs per plant. Similarly, Diaz-Zorita (200), Varse et al., (1997) and Salarzai, (2001), who reported deep tillage and herbicides application significantly increase the grain yield.

Conclusion

Based on the present study finding, it is concluded that mould board plough should be used for land preparation and pendimethalin @ 990 g a.i. ha^{-1} should be sprayed just after sowing for control of weed and obtaining higher yield of maize under the Faisalabad condition, Pakistan.

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